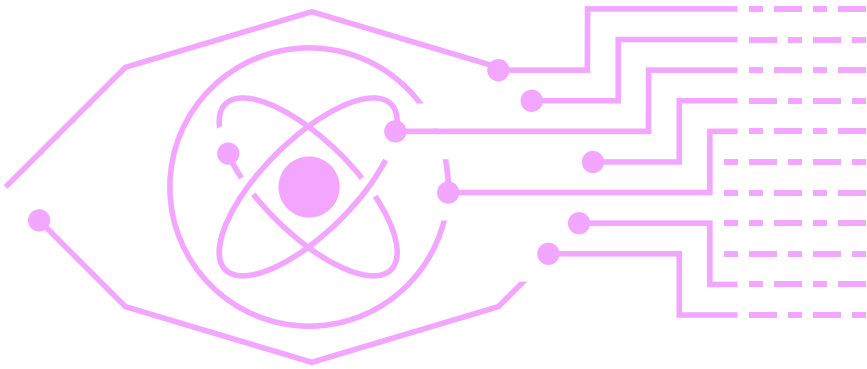
A sensXPERT Deep Dive

Discover the Building Blocks of a Dynamic Process Control Solution

sens X PERT

EXPAND your sense of the possible



CONTENTS

Decreasing up to 50% of existing scrap, increasing up to 23% of energy savings, and reducing up to 30% of cycle times, sensXPERT Digital Mold is an advantageous process control solution for manufacturing processes in the plastics industry.

The sensXPERT Digital Mold solution has been designed and developed to integrate into numerous processes, such as reaction injection molding, resin transfer molding, compression molding, autoclave curing, and more. From the aviation and automotive industries to the construction and energy industries, sensXPERT's solution combats industry challenges by tracking and optimizing existing processes.

But how does Digital Mold work? In this white paper, you will gain insights into the various components that make up sensXPERT Digital Mold. You will have access to the inner workings of the sensXPERT material characterization sensors, edge device, edge device interface, and digital Cloud service. Read on for a deep dive into sensXPERT.

sensXPERT Material Characterization Sensors

Material characterization is invaluable in plastics manufacturing. Through the implementation of material characterization tests, manufacturers can ensure the quality, performance, and safety of their final products.

There are numerous material characterization techniques and tests that can be conducted at different stages of production. This section will examine in-mold material characterization in specific.

Additionally, we will shed light on the innovative sensXPERT material characterization sensors that monitor material properties during production to enhance control and quality in different manufacturing processes.

What is Material Characterization?

Material characterization methods are used to investigate and measure various materials to identify their physical, thermal, mechanical, and chemical properties. Material characterization enables engineers to select the most suitable and appropriate materials for specific products, as well as ensure that final products are safe, efficient, and durable.

Traditional material characterization techniques are conducted in laboratory settings, where environments are controlled, specialized personnel and equipment are readily available, and testing procedures are standardized.

However, conditions are not as regulated and controlled during plastics manufacturing as they are in a laboratory environment. Therefore, the material data gathered in a lab cannot be fully applied to material behavior and properties during production.

Additionally, lab-based material characterization is not a real-time procedure, so it cannot account for fluctuating or dynamic circumstances within a manufacturing process.

So, what is the alternative? The answer is using industrial sensor technologies capable of conducting material characterization within the manufacturing environment, specifically to collect data on material behavior while it undergoes processing.

To identify the properties of plastic materials in real-time, in-mold material characterization is necessary, which is why sensXPERT developed material characterization sensors to be directly integrated within the mold.

Sensor Technology

Before looking at sensXPERT's material characterization sensors, it is worth highlighting the other types of sensor technologies that have been developed for applications in industries ranging from healthcare to consumer electronics.

Sensor technologies aim to detect and measure physical properties or changes in the environment and convert them into electrical signals. The electrical signals are then processed, analyzed, and used for diverse applications.

Sensor technologies generally operate based on sensing principles, which relate to the physical properties the sensors are meant to determine. To name a couple of examples, the principle of thermal expansion or electrical resistance changes with temperature are two of the many methods that temperature sensors might wield.

What Other Types of Sensor Technologies Are There?

We have touched upon material characterization sensors and will dive into them further. We also briefly mentioned temperature sensors, but beyond these two, several other sensor technologies are used in the plastics manufacturing industry. Among these are:

- Pressure sensors: to detect and measure pressure changes.
- Humidity sensors: which measure moisture content in the air.
- Proximity sensors: to detect the presence or absence of an object without physical contact.
- Flow sensors: to monitor the rate of flow in pipes and channels.
- Gas sensors: used to detect the presence and concentration of specific gases.
- ·Accelerometers: which measure acceleration forces and vibrations.

How Do In-Mold Material Characterization Sensors Compare?

While the listed sensor technologies have their advantages, the specialized nature of in-mold material characterization sensors makes them distinctly valuable for plastics manufacturing. In-mold material characterization sensors are designed for specific use in plastics manufacturing processes, and their primary purpose is to provide real-time data on material behavior while it is being processed.

The collection of real-time data also sets these sensors apart from the previously listed technologies, as instantaneous data enables manufacturers to monitor and adjust their process parameters directly. The other sensors may not be as immediately actionable during production.

Additionally, in-mold material characterization sensors, as the name suggests, are integrated into the mold, which ensures their direct contact with the processed material.

Overall, the design, integration, and real-time data acquisition of in-mold material characterization sensors make them uniquely suited for optimizing manufacturing processes and guaranteeing final part quality and performance.

Deep Dive: sensXPERT Material Characterization Sensors

As part of the sensXPERT Digital Mold solution, sensXPERT's material characterization sensors can monitor a variety of materials, including:

- Thermosets
- Thermoplastics
- Elastomers
- Composites

You can read more on the plastic industry's materials landscape in this article.

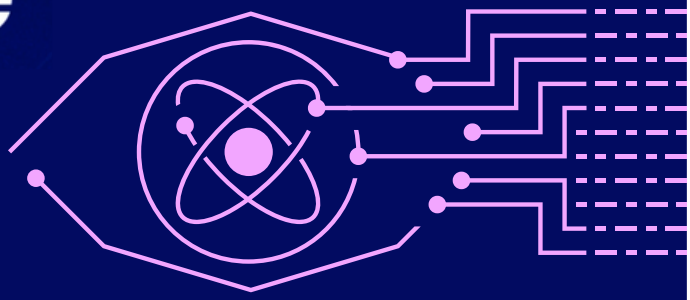
The sensXPERT sensors uniquely make use of dielectric analysis (DEA), which examines how molecules behave in an electrical field. This data is then used to determine the material's degree of cure or crystallization, viscosity, glass transition temperature, and more.

The sensors are placed in small holes in the mold to have direct, continuous contact with the material throughout its molding process. With this contact, the sensors can record changes in the material's dielectric response.

sensXPERT's material characterization sensors have been specially designed to withstand industrial manufacturing temperatures and pressures. The sensors are also scratch and solvent resistant. The highly durable sensors can steadily operate under temperatures of up to 280°C and pressures of up to 400 bar.

Moreover, all the data gathered by the sensors are transferred to the sensXPERT edge device, which will be expanded upon in the upcoming section. This valuable real-time data is used to calculate and predict material properties that are critical to final part quality.

What happens in the mold is invisible



The sensXPERT Edge Device and Interface

If you have read up on our sensXPERT Digital Mold solution or tried out our illuminating **AR Experience**, then you might be aware of the vital role played by the sensXPERT edge device in collecting and transferring process data. You might have also learned about on the edge device interface, which allows machine operators to monitor their molds and manufacturing processes in real-time.

Having discussed **material characterization sensors** above, we are highlighting the second and third core components of our process intelligence solution in this section. The edge device is a compact, hardened industrial personal computer (IPC) loaded with our machine learning algorithms. Simultaneously, the edge device interface visually displays all process and material behavior data as it is collected and processed by the edge device.

What is an Edge Device?

As physical pieces of hardware or equipment, the primary purpose of an edge device is to move data processing and storage away from large data centers, such as the Cloud, and closer to spaces in which data is generated.

The device's name stems from its positioning at the "edge" of a network. Edge device use has expanded with the development of the Internet of Things (IoT) and Cloud computing because of an increased need for greater computing power, intelligence, and more responsive data processing.

Some examples of edge devices are:

- **Internet of Things (IoT) devices** – such as sensors, smart home appliances, and industrial machines- generate, locally process, and transmit relevant data and information to the Cloud.
- **Autonomous Driving** – in which data generation and processing occurs directly within a car.
- **Smartphones** – which can locally process data, regardless of an internet connection, and, once possible, sync data to cloud services.

Regarding our sensXPERT edge device, the powerful IPC is the main junction between our material characterization sensors and the digital Cloud service.

sensXPERT Edge Device: Designed for Industrial Environments

Industrial environments can be rough on fragile electronic devices, especially when close to a hot press or potentially at risk of dust contamination. Consequently, our sensXPERT team designed the edge device with fluctuating temperatures, humidity, dust, and other factors in mind to ensure durability

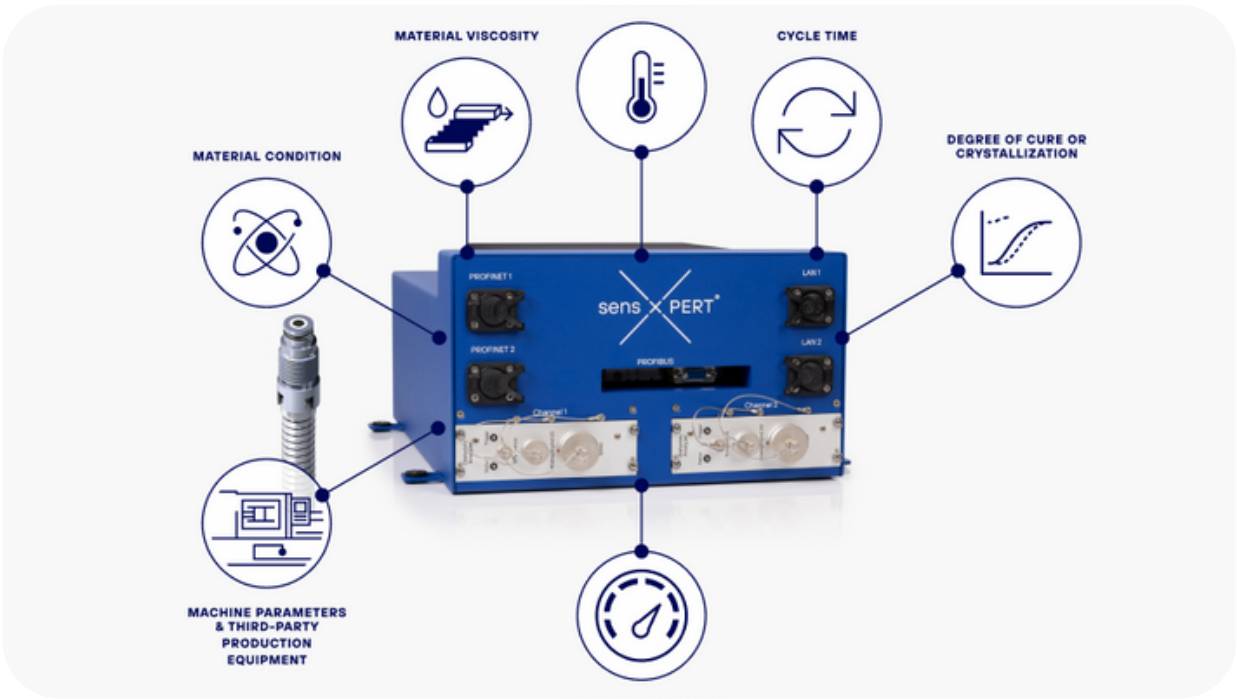
Additionally, rather than using conventional fans and filters, the edge device uses a passive cooling system that is more effective at preventing overheating an

d resisting dust or other contaminants. Furthermore, covers that seal off any sockets or outlets on the edge device unit are supplied to customers to maintain a clean interior.

Considering the conventionally limited space available on shop floors, our edge device – fashioned in sensXPERT blue – is compact and can be mounted horizontally on a table or vertically on a post or column. This flexibility provides manufacturers with increased installation options to ensure the IPC is adjacent to their sensXPERT-instrumented mold and press without disrupting mobility.

Along with the sensXPERT material characterization sensors, the edge device is compatible with and can connect to third-party pressure transducers, mold temperature, ambient temperature, and humidity sensors. Being closely positioned to the instrumented mold ascertains high-quality electrical signals between the edge device and the sensors.

Additionally, each sensXPERT edge device has been manufactured/designed to accept a 24V DC power supply, which nearly every cabinet in a production environment is wired to distribute.



sensXPERT Edge Device Interface

Moreover, the sensXPERT edge device interface is a platform that displays the entire array of process and material parameters per part produced. Using this interface, machine operators can view accurate, real-time predictions on the trajectory of a material's degree of cure or crystallization, glass transition temperature, and other properties.

The interface also gives operators insight into when a cycle will have reached the desired point of cure or crystallization. With this information, operators are empowered to dynamically adjust and optimize their processes as they progress, thus making sure that all parts produced will be of the highest quality.

Ready for Industry 4.0 and Beyond

Our edge device accepts both analog and digital signals from molding machines and presses.

These incoming signals provide real-time information on what occurs within the machines during production, thus enabling greater process tracking. Furthermore, all of the data collected from the previously mentioned sensors can be integrated into machine learning algorithms for increased predictive accuracy on material behavior.

Additionally, to make our edge devices compatible with the automation and digital twin/digital thread characteristics of Industry 4.0 and beyond, they come preloaded with OPC-UA, PROFIBUS, and PROFINET field bus interfaces.

More interfaces enable more connected manufacturing operations, allowing increased data exchange between the press, our edge device, local LAN systems, and our digital Cloud service.

Software Increases Functionality

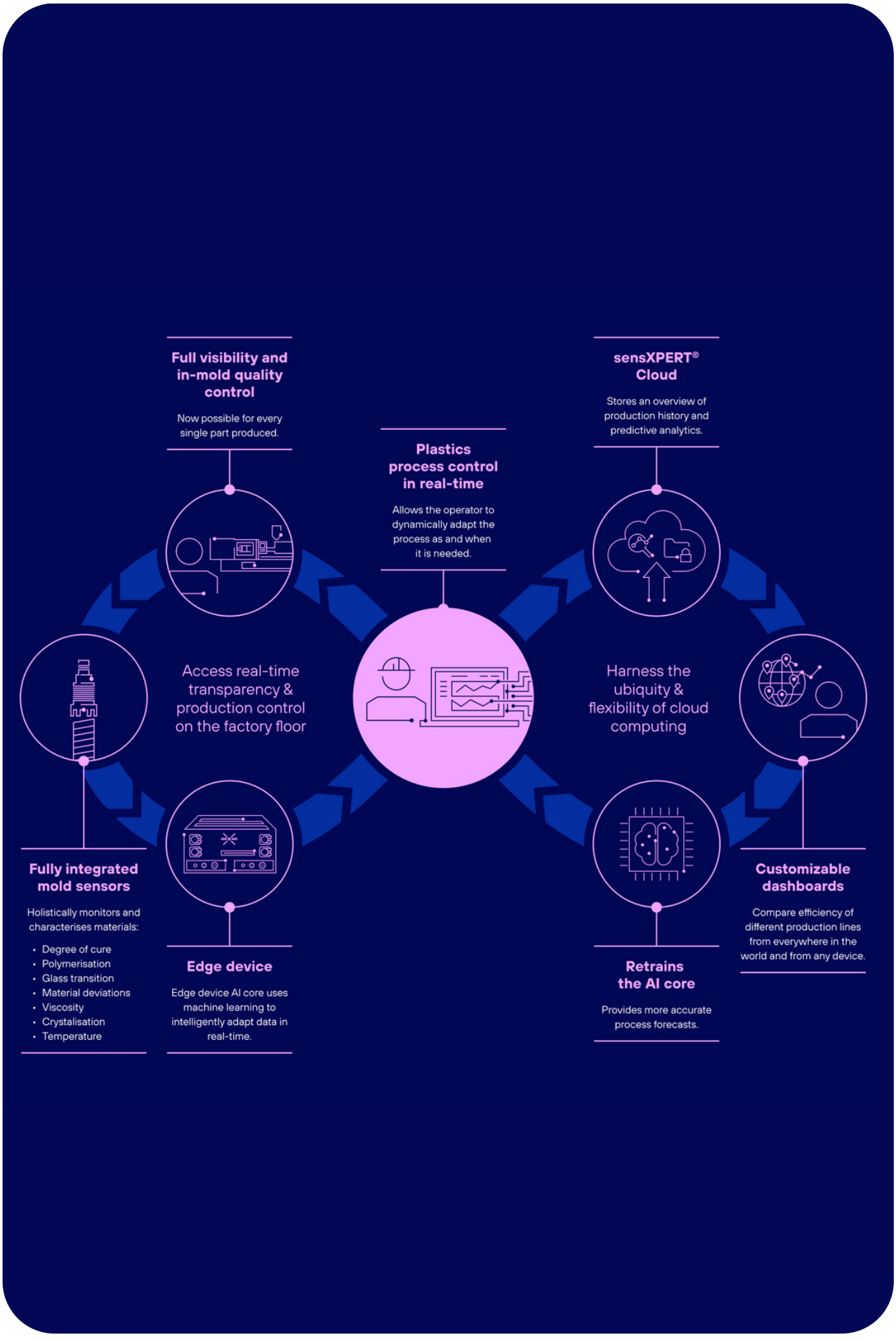
sensXPERT edge devices are equipped with the latest generation of software and machine learning algorithms, which are developed by our sensXPERTs to enhance process control capabilities, increase system functionality, and supply manufacturers with faster access to information on their molding processes.

Being a process control solution, sensXPERT Digital Mold relies on several features that effectively accomplish dynamic process adaptation. One such feature is a stop trigger, which is sent to the machine via the edge device as soon as a process reaches the desired degree of cure or crystallization. As the name implies, the stop trigger automatically stops the molding process, thus reducing manual effort and optimizing cycle times.

As will be expanded upon in the following section on the sensXPERT digital Cloud service, the edge device sends all collected sensor data to the Cloud to retrain **machine learning algorithms**. The Cloud also presents a database with the entire history of a sensXPERT-integrated process.

Benefits of the sensXPERT Edge Device and Interface

- ·A measuring device and industrial PC combined in a single unit.
- The device is hardened to protect it from heat, dust, and vibrations in industrial environments.
- Industry 4.0 automation-ready and can share a broad range of data with local LAN systems and the digital Cloud service.
- The interface is continuously updated and enhanced.
- Manufacturers can monitor their production in real-time and gain valuable insights.
- ·Processes can be dynamically adjusted and controlled, which decreases manual effort and optimizing cycle times.



The sensXPERT Digital Cloud Service

In the last two sections, we introduced three components of our Equipment-as-a-Service sensXPERT Digital Mold solution. Specifically, we covered the sensXPERT **material characterization sensors, edge device, and edge device interface.** To round out this white paper, we will take a closer look at the final element of Digital Mold – the sensXPERT Digital Cloud Service.

Developed in collaboration with Amazon Web Services (AWS), the sensXPERT Digital Cloud Service – hereafter referred to as the sensXPERT Cloud – is a digital environment aimed at furthering Manufacturing 4.0 in the plastics manufacturing industry.

Before fully tackling the final part of our solution, this section will outline the basics of cloud computing technology. After grasping the basics, we will break down sensXPERT's use of cloud computing technology, its connection to machine learning, and the advantages of the sensXPERT Cloud for manufacturers.

What is Cloud Computing Technology?

Cloud computing is the digital offering of computing resources – servers, databases, and storage – through internet-connected devices. Internet-connected devices include smartphones, computers, tablets, etc.

The computing resources are typically hosted at data centers that cloud service providers, such as AWS, manage.

Additionally, cloud computing offers many advantages, such as cost and time savings, which have propelled many organizations into seeking out cloud computing services.

The following encompasses a few more key benefits of cloud computing technology:

- ·**On-Demand Access**: Cloud users can access cloud services, such as storage and applications, as desired and without reliance on physical hardware or local infrastructure.
- ·**Scalability**: Organizations and users can flexibly scale their use of Cloud services up or down based on demand.
- ·**Resource Sharing**: Multiple users or organizations can use the same physical infrastructures when using Cloud services, thus leading to efficient resource utilization.

How Does Edge Computing Compare?

The previous section highlighted the sensXPERT edge device, which utilizes edge computing. sensXPERT Digital Mold is valuable in its use of both edge and cloud computing, but how do they compare?

While cloud computing, as previously mentioned, delivers remote resources through cloud service providers, edge computing processes and analyzes data closer to the sources of data generation.

Cloud computing succeeds in its handling of large-scale data processing and storage. On the other hand, edge computing excels in real-time data processing.

Despite each having its advantages, the two types of computing can also complement one another. sensXPERT reaps the benefits of edge and cloud computing through the sensXPERT edge device, edge device interface, and Cloud service.

The sensXPERT edge device and interface employ edge computing to process data at the edge for real-time action and insights. As will be further elaborated upon, the sensXPERT Cloud wields cloud computing to aggregate and analyze data. Additionally, cloud computing and the sensXPERT Cloud allow for deeper analysis and observation of broader process trends.

How Does sensXPERT Use Cloud Technology?

The sensXPERT **material characterization sensors** collect in-mold data, and the **edge device and interface** use the data to conduct real-time process analysis and predict process outcomes. The sensXPERT Cloud is the final component of sensXPERT's digital manufacturing solution.

sensXPERT's digital capabilities are cultivated in the sensXPERT Cloud. At its most foundational level, the sensXPERT Cloud stores and visualizes all process data to manufacturers. Everything collected and calculated by the edge device is effectively transmitted, validated, and displayed in the sensXPERT Cloud.

All of this information is presented in the form of customizable graphs and dashboards. These dashboards can be customized to track process trends and performance based on specified parameters. At the same time, any parameter deviations or variations can be highlighted to aid process engineers in identifying causes of errors or areas of optimization in production.

Additionally, sensXPERT facilitates interconnectivity. If a manufacturer has several sensXPERT-connected machines across various locations, they can log in to their sensXPERT Cloud account and remotely compare data from multiple sites. The Cloud dashboards provide an overview of the different processes and machines, whether on a global or more local scale.

Moreover, while the edge device uses predictive machine learning algorithms, the sensXPERT Cloud facilitates machine learning retraining. Machine learning retraining is essential for reacting and adapting to potential changes in the manufacturing process, such as material aging and other influential factors that may change over time.

Retraining in the sensXPERT Cloud is triggered by changes in manufacturing conditions or the availability of new data. Therefore, the retrained models can be returned to the edge device and applied to subsequent cycles with condition changes being accounted for.

Advantages of the sensXPERT Digital Cloud Service

With customizable dashboards, interconnectivity, machine learning retraining, and abundant insightful information, manufacturers also gain several advantages using the sensXPERT digital Cloud service.

A Digital Thread Per Part Produced
By storing, visualizing, and hosting all measurement data previously recorded by sensXPERT, the sensXPERT Cloud offers a digital thread per part produced. All of the measurement data can also be downloaded from the sensXPERT Cloud.

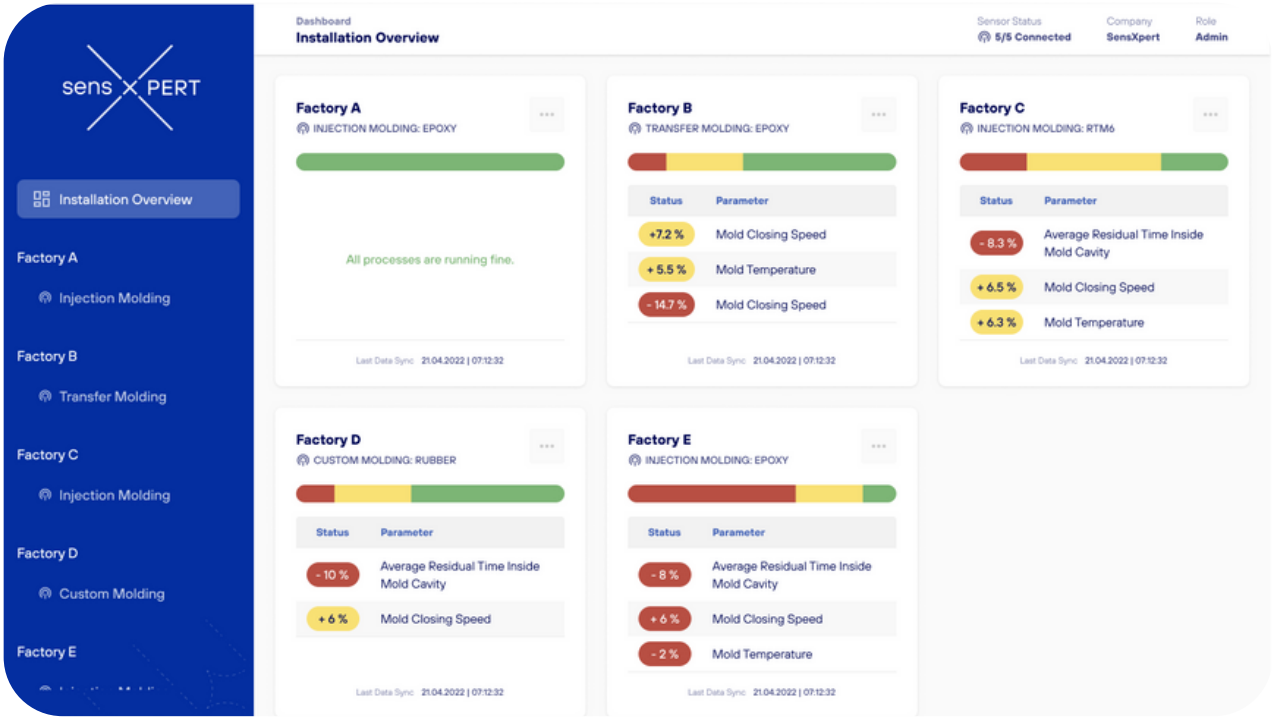
This allows for a comprehensive record of a plastic part's entire production cycle, which is beneficial in adhering to regulatory reporting requirements – such as the EU Taxonomy.

Additionally, a digital thread is beneficial for quality assurance in manufacturing. For instance, if defects or errors are found in a plastic part's downstream quality assurance tests, the digital record of the part's in-mold behavior can ease finding the cause of the error.

Remote Process Tracking
The sensXPERT Cloud allows manufacturers to track all their processes remotely. With an active internet connection, Cloud users can visualize the processes and identify the trends within their entire manufacturing network from anywhere.

Process Intelligence and Optimization
The sensXPERT Cloud generates process-level overviews following completed cycles. By comparing different completed cycles and process data across a business' manufacturing network, the sensXPERT Cloud benefits manufacturers by identifying areas of improvement and optimization.

On top of that, consistent machine learning retraining guarantees the refinement of process intelligence in the manufacturing environment.



With that, we wrap up our white paper on the sensXPERT Digital Mold solution. In summary, we explored **material characterization** and sensXPERT's durable sensor technology, then we highlighted the robust, real-time predictive capabilities of the **sensXPERT edge device and interface**, and we ended by tackling cloud computing and our sensXPERT digital Cloud service.

If you want to further discover and dig into the benefits of sensXPERT Digital Mold, head to our '**How does sensXPERT work?**' page and try out the interactive AR Experience.

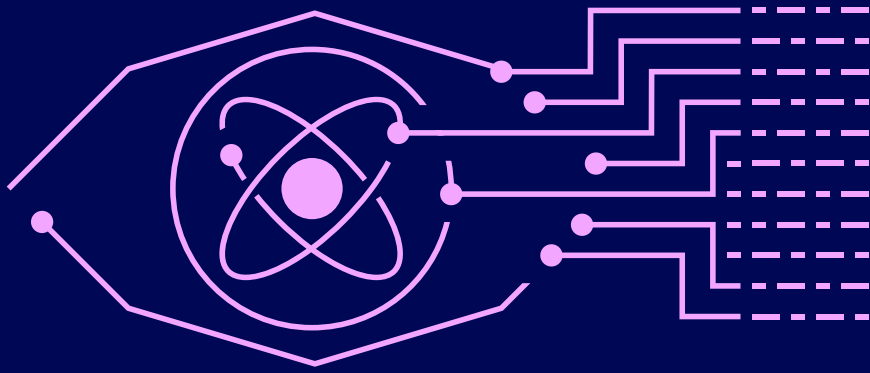
Are you interested in discovering how sensXPERT can optimize your specific manufacturing processes? Reach out to our sensXPERTs via the **contact page**.

Learn more at www.sensxpert.com or contact the team at www.sensxpert.com/contact

NETZSCH Process Intelligence GmbH
19 Gebrüder-Netzsch-Straße
Selb, 95100 Germany

+49 9287919184
info@sensxpert.com
www.sensxpert.com

LinkedIn



sensXPERT

EXPAND your sense of the possible